violet, the sensation equation to white was determined. The other colours of the spectrum were then used in forming white, and from their luminosity equations their percentage composition in sensations were calculated. The percentage curves are shown. The results so obtained were applied to various spectrum luminosity curves, and the sensation curves obtained. The areas of these curves were found, and the ordinates of the green and violet curves increased, so that both their areas were respectively equal to that of the red. This gave three new curves in which the sensations to form white were shown by equal ordinates.

A comparison of the points in the spectrum where the curves cut one another, and of those found by the red and green blind as matching white, show that the two sets are identical, as they should be. The curves of Koenig, drawn on the same supposition, are called attention to, and the difference between his and the new determination pointed out.

The red below the red lithium line, as already pointed out, excites but one (the red) sensation, whilst the green sensation is felt in greatest purity at λ 5140, and the blue at λ 4580, as at these points they are mixed only with the sensation of white, the white being of that whiteness which is seen outside the colour fields.

"The Conductivity of Heat Insulators." By C. G. Lamb, M.A., B.Sc., and W. G. Wilson, B.A. Communicated by Professor Ewing, F.R.S. Received May 3,—Read June 15, 1899.

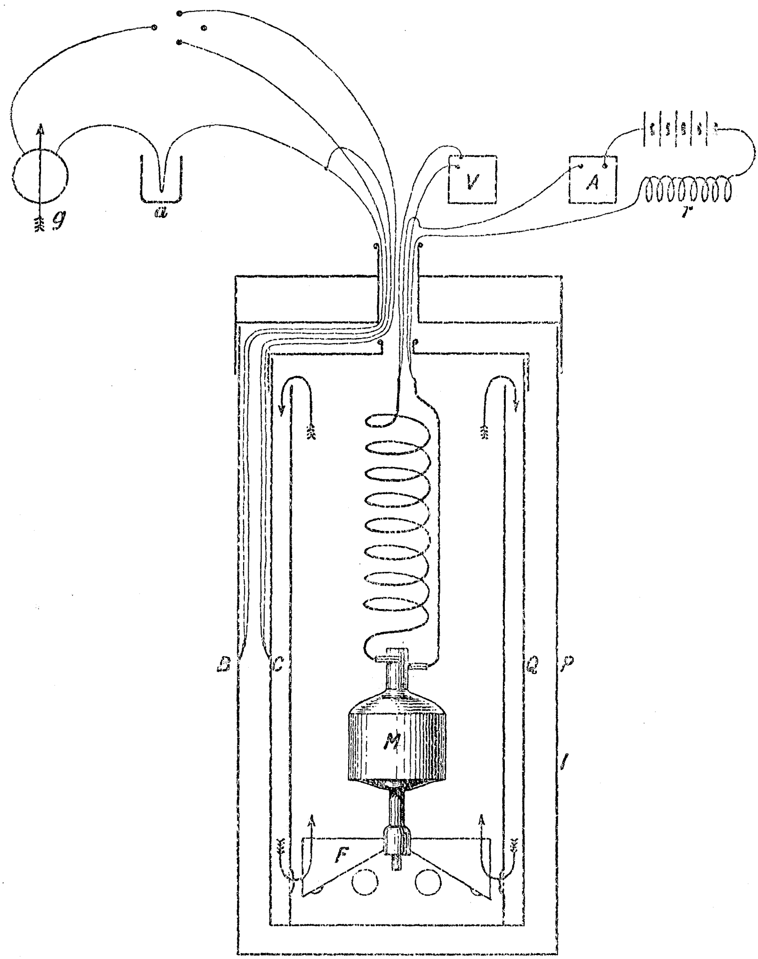
The comparative efficiency of materials used as insulators has been the subject of several investigations; the majority of these have been conducted at fairly high temperatures, and it may be questioned whether the results can be applied to the same materials when used as a lagging to protect bodies at low temperatures. Moreover the methods adopted do not seem susceptible of any considerable accuracy. The method to be described was devised with the object of using lower temperatures and smaller ranges than had been used in previous experiments, to attain a perfectly steady state of heat transference, and allow of greater accuracy and simplicity in the measurements.

The substances selected for experiment so far have been those which could easily be tested in the dry state, without being made up into cements; they include air, sawdust, charcoal, pine shavings, paper, asbestos, sand, silicate cotton, hair felt, rice husks, and a heat insulator known as "kapok."

The method employed consisted in placing the material under test in the space between two cylindrical copper pots, kept at a definite distance apart by pieces of vulcanised fibre; the inner pot contained a small

motor with a fan attached to the axis; a tin-plate cylinder, open at the top and with holes at the bottom, was put inside to direct the currents of air over the inner surface of the inside pot, in the direction of the arrows shown in Fig. 1. Energy was supplied electrically to a heating

Fig. 1.



coil within as well as to the motor: this constituted an internal supply of heat, which maintained the temperature within the pot at any decided upper limit. The motor and heating coil were connected in series, and leads were carried through a small hole in the lid of the pots to measure the current and potential difference, and thus the

power expended on internal heating was measured. The outer pot was immersed in a tank kept overflowing from the water main, the lid of the pot being made into a sort of saucer, into which the incoming water ran, thus the outer pot's surface was kept at a uniform and constant temperature. The resulting temperature differences were measured by means of thermo-electric junctions of copper and iron, in a way shortly to be described. The current was allowed to pass steadily into the inner pot, driving the motor and fan, until the inner thermo-electric junction arrived at a steady value; this usually occurred in about three hours or so; when this was the case, the supply of energy by the current was just equal to the heat conducted through the insulator and carried off by the water. Knowing the temperature gradient and the number of watts supplied and the dimensions of the system, we can deduce the specific conductivity of the material.

The general arrangement is shown in Fig. 1. (P) is the outer pot which stood in the tank; its approximate dimensions were 8 inches in diameter and 16 inches high; (Q) is the inner pot, with one inch clearance between it and the outer one; outside are shown the voltmeter (V), ammeter (A), and adjustable resistance (r); inside the pot (Q) are a fixed resistance (R), the motor (M), and fan (F). To a point about the middle of each pot, inside the outer, and outside the inner, are soldered the copper-iron junctions B, C, which are brought outside to a three-way plug and a galvanometer. a is a junction placed in a vessel of water at a known temperature; g is a galvanometer of the Crompton-D'Arsonval pattern. The junctions used were always made of exactly the same length to keep the total resistance constant, and on calibration were found to give a linear relation between temperature difference and deflection on the galvanometer within the ranges which were to be used, and during each experiment a check calibration at two known temperatures was made by means of a third junction in water at another known temperature. When a steady state was attained, the temperatures of B and C above A were measured by the deflections and calibration tests. The reason for the above indirect method of measuring the difference of temperature between B and C was to avoid possible leakage currents. The flow of heat per second from the inside pot to the outside one will be given by the expression $H = \lambda c \theta$, where c is the specific conductivity, θ is the temperature difference, λ is a constant depending on the size of the pots, being the area in square centimetres of two plane surfaces, distant one centimetre apart, that would permit the same flux of heat as the actual arrangement employed under the same conditions of heat transference and temperature gradient. The value of λ was calculated from careful measurements of their dimensions, on the assumption that the flow of heat could be taken as radial for the sides, and from the top and bottom of the inner, to the bottom and top of the outer, pot; this leads to the expression

$$2\pi\left(\frac{l_1}{\log_\epsilon \frac{r_2}{r_1}} + \frac{r_1^2 + r_2^2}{l_2 - l_1}\right)$$

for this quantity, where l_1 and l_2 are the lengths, r_1 and r_2 the radii of the pots. This gives for λ the value 1560 when the lengths are measured centimetres. If W denote the rate of supply of energy in watts, the rate of transference of heat in gram-C°-units when the steady state is attained will be $H = 0{\cdot}239$ W. Hence, if c is the specific conductivity, and θ the temperature gradient,

$$H = 1560\, c\theta;$$

therefore

$$c = 0{\cdot}000153\, \frac{W}{\theta}.$$

Two points had to be settled before the determination could be evaluated:—(1) Whether the temperature was uniform over both copper pots; (2) whether any part of the temperature gradient was due to a sudden drop at the surface of separation. As regards the outer pot, since it is wholly surrounded by water, its temperature must be uniform, and the inside and outside can only differ by the drop through the copper, which is eliminated by putting the junction inside that pot; to test the question as regards the inner pot (and partly as regards the outer one) junctions were placed at various points on the surfaces, as well as at certain other points, as shown in Fig. 2. The result of this experiment is given below.

Junction.	1	2	3	4	5	6	7	8	9
Temperature relative to 8	25·6	25·6	25·4	25·2	13·8	0·6	0·6	0	28·1

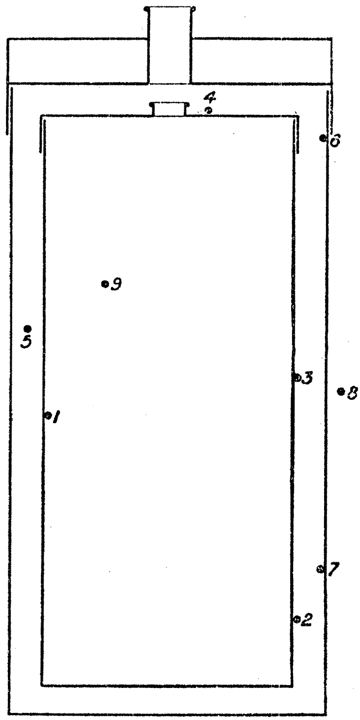
It will be seen that the temperature over the surfaces of the pots was practically uniform, and hence the determination of the gradient could be satisfactorily determined from readings taken with one junction on each pot, as at first described.

The second point was tested as follows:—A third pot was provided, having a clearance of 1 inch with regard to the former larger pot; under similar conditions as to character of insulator and power supplied the temperature gradients in the case of the two combinations of small and medium, and small and large, pots were measured; the ratio was found to be 0·54. The value of λ for the new arrangement of small and large pots was calculated, and found to be 840 in centimetre measure, being thus 0·538 of the standard combination. The close

agreement between these values shows that no appreciable drop occurs at the separating surfaces.

These points being settled, the various substances named above were

Fig. 2.



Material.	Temperature differences.	Watts supplied.	Watts per 1° C.	*c*.
Air (no baffles)	19·2	25·0	1·30	0·000200
Pine sawdust	19·8	31·7	1·58	0·000242
Pine shavings...............	19·5	20·8	1·06	0·000162
Brown paper (crumpled up) ..	20·2	22·0	1·09	0·000167
Hair felt (broken up)........	25·8	24·5	0·95	0·000145
Hair felt in two sheets, ½ inch thick each	27·2	18·9	0·69	0·000106
Dry asbestos	14·9	29·0	1·94	0·000297
Charcoal	27·8	27·2	0·98	0·000150
Sand	8·0	39·0	4·85	0·000740
Rice husks.................	14·0	13·7	0·98	0·000150
Kapok (tight)	23·2	21·8	0·94	0·000144
Kapok (loose)	27·8	22·3	0·80	0·000122
Silicate cotton	24·7	24·5	0·99	0·000151

placed between the pots, and the watts and temperature gradients were determined in the manner described. At least two tests of each material were made, the mean temperature throughout being about 40° centigrade. The results are given in the table (p. 287).

It will be noticed that hair felt was the best insulator that was tested. The insulation in the case of brown paper was practically that of air with subdivided spaces, as the paper occupied relatively a small volume; a comparison of this with insulation by air only will show how great an improvement in air-lagging such a simple expedient will give.

In repeating the experiments with wider ranges and a higher mean temperature, indications were observed tending to show that the conductivity is a function of the temperature. It is hoped to continue the investigation as regards this point, and to extend it to other insulators.

"On the Orientation of Greek Temples, being the Results of some Observations taken in Greece and Sicily, in May, 1898." By F. C. PENROSE, M.A., F.R.S. Received May 5,—Read June 15, 1899.

(Abstract.)

The orientation of the Cabeirion Temple, near Thebes, of which the angle has been disputed (see p. 46 in my paper of 1897), was remeasured with the theodolite in May, 1898, and the previous observations confirmed. An additional example is added from an archaic Temple of Neptune in the Isle of Poros, introducing the employment of the bright zodiacal star Regulus, which I had not before met with.

In Sicily the re-examination of the temples at Girgenti, where, in my former visit, I had relied for azimuth on the sun's shadow and the time, has enabled me to give to the elements some amendments in detail, the only point of consequence being, that the orientation date of the temple named Juno Lacinia is brought within the period of the Hellenic colonisation of that city.

The most interesting point in the paper seems to be, that in the case of two Athenian temples, namely the Theseum and the later Erechtheum—*i.e.*, the temple now partially standing—it is shown that the days of those months on which the sunrise, heralded by the star, illuminated the sanctuary, coincided exactly, on certain years of the Metonic cycle, with the days of the Athenian lunar months on which three important festivals known to be connected with at least one of those temples were held. The years so determined agree remarkably well with the probable dates of the dedication of those temples; and in the case of the first mentioned, the festival, which was named The Thesea, seems to leave little doubt that the traditional name of the temple, which has recently been much disputed, is the correct one.

FIG. 1.